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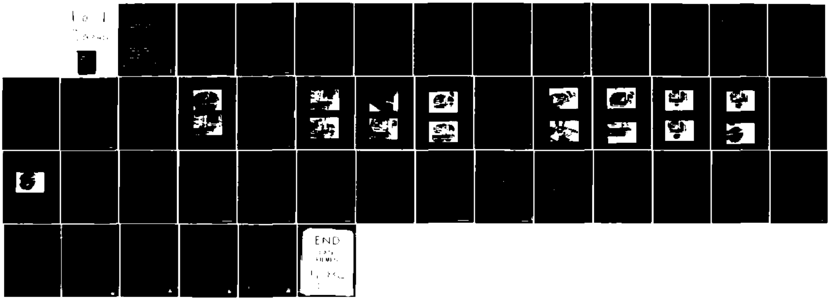

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Research and Development Technical Report
CECOM-81-C-0085-1

FIELD EXPEDIENT REPAIR OF FIBER OPTIC CABLES

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TRW INC.
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Research and Development Laboratories
Philadelphia, PA. 19108

May 1982

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Fiber Optic Splice

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This Interim Report describes the design of a field expedient fiber optics cable splicing system. The field splice kit will include a manually operated splicing machine which has all of the tools for making the cable repair mounted on a single platform, transportable in a hand-carried or back-packed case. The splice consists of glass four-rod alignment guides pre-mounted in a splice housing. Means are provided for fiber and cable retention in the housing to effect a rugged cable repair.

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The procedure for making the cable repair is outlined and described with the aid of a series of photographs of a wooden model of the splicing machine. The manipulations required to make the splice are designed to be simple and performable under adverse field conditions.

PREFACE

This is the first Semi-Annual Report for the work being performed on contact number DAAK80-81-C-0085, "Field Expedient Repair of Fiber Optic Cables". The funding for the development of the repair system is provided by the U.S. Army Communications - Electronics Command (CECOM). Technical direction and coordination is provided by Claire E. Loscoe, the cognizant engineer at CECOM.

The design phase work performed to date represents the efforts of: Dr. Malcolm H. Hodge, Manager, Fiber Optic Devices; Joseph F. Larkin, Senior Mechanical Engineer; Henry D'Amico, Design Engineer; and John G. Woods, Program Manager. All are members of the TRW Electronic Components Group, Research and Development Labs. in Philadelphia.

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1.0 INTRODUCTION

The concept of field repair of tactical communications cable is a new one. When twin metallic coaxial cable is damaged, connectorized sections are replaced in the field. Fiber optic cable will be deployed in lengths of one kilometer or more, making it attractive to consider temporary field repairs for rapid restoration of service.

This report is the first semi-annual progress and status review of an exploratory development program to obtain a field expedient repair technique, and tool kit, for fiber optic cable. The concept being developed involves the use of four-rod glass alignment guides to provide precise fiber alignment. The guides are enclosed in a splice housing to give the repair the mechanical strength and protection to maintain the communication link. The tools for stripping and preparing the fiber ends will be built into one assembly for ease of operation in the field.

Throughout the report, the complete cable repair is referred to as a "repair" or as a "splice", and includes the alignment guides, cable retention means and splice housing, or enclosure.

2.0 TECHNICAL DISCUSSION

The Technical Requirements for the field expedient repair are given in the contract and reproduced as Appendix A of this report. The selection of cables and the preliminary designs are based on the guidelines presented in the Requirements. The interim repair samples will prove viability of the splice system, but will not demonstrate repair of the complete range of cable sizes and ability to repair one or more fibers without interrupting the functioning channels. These latter variations will be addressed later in the program.

2.1 Fiber Optic Cables

At the beginning of the program, 50 to 200 meter lengths of the following fiber optic cables were purchased:

1) Galite #6050-SD duplex cable.
2) ITT #T2000-02 tight buffer, duplex cable
3) ITT #T2001-06 tight buffer, 6 fiber cable.
4) Siecor #212 loose filled buffer, duplex cable
5) Siecor #204 tight buffer, duplex cable.
6) Siecor #6S6D0173, loose filled buffer 6 fiber cable.

The fibers in all of the above cables have 125μm O.D./50μm cores, except the Siecor #212, which is 125μm O.D./63μm core.

During our investigations and discussions with CECOM personnel, it was determined that the near-term applications for the splice kit will be for duplex cable. It also appears that it is desirable to plan for cable having two polyurethane jackets, as well as two layers of Kevlar strength members. The only cable purchased having the double jacket construction is the ITT #T 2001-06 six fiber cable. It has been decided, therefore, that the interim repair samples will be prepared with the six fiber cable, but using only two fibers. The repair process can be easily adapted to single-jacketed cable, if desired. It will also be assumed for the interim samples that a complete cable break has occurred, rather than only one channel broken and that communication through the unbroken fiber is not sufficiently critical as to preclude its temporary loss during total fiber repair.

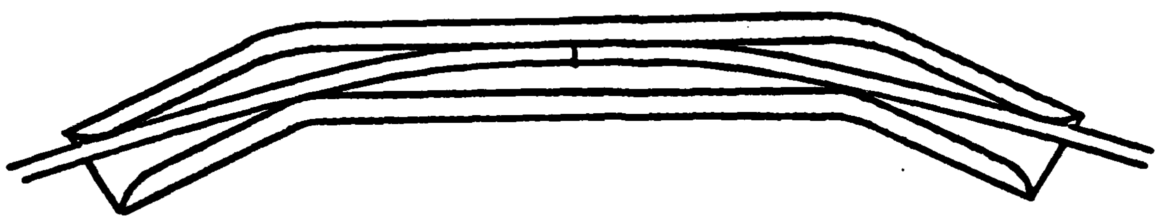
2.2 Splice Design Concept

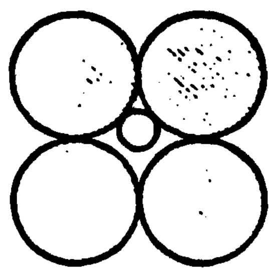
The basic element in the optical fiber splice is the four rod alignment guide, which has been described in published papers.[1,2] Figure 1 is a schematic illustration of the guide concept. Fiber/fiber alignment is effected by a vee-groove formed by the cusp of the four drawn and fused glass rods. The two cleaved fiber ends of each channel to be repaired are forced into the same vee-groove because of the double elbow formed in the guide. The size of an alignment guide is governed by the size of fiber to be joined. For 125 um diameter fiber the guide is approximately .040 in. (1.0mm) across flats and 0.75 in. (19.1mm) long.

The alignment guide provides a connection having an insertion loss of less than one dB, with dry 125μm/50μm fibers, properly cleaved. The loss is considerably reduced by the simple expedient of having a liquid at the fiber interface. With a silicone fluid, typical insertion loss is 0.3dB or less, because of the virtual elimination of face reflection and Fresnel loss. The addition of the liquid is also forgiving of minor defects in the cleaved fiber surface. The alignment guides will be pre-filled with silicone fluid, at the factory. The fluid is retained in the guide by its own surface tension. A 100 CS viscosity, at room temp-

TRW FIBER ALIGNMENT GUIDE

LENGTHWISE SECTION





END CROSS SECTION
(ENLARGED)

fig.1

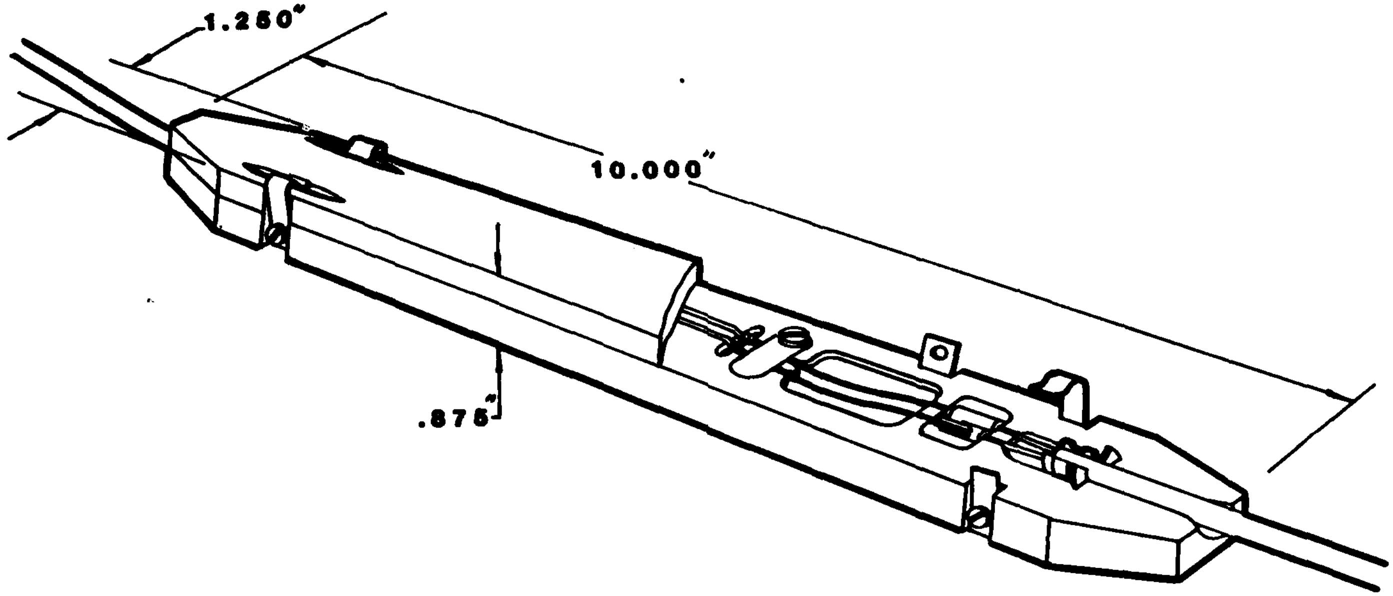
rature, assures a full operational capability over the $-55^{o}C$ to $100^{o}C$ temperature range.

The alignment guide, while it is the heart of the splice system, is not considered a fiber or cable splice in itself. The fibers must be positioned and retained in a housing, which must also provide retention of the cable's strength members, as well as environmental protection for the fibers and guides.

A drawing of the splice is shown in Figure 2, with the cable in place. The alignment guides are factory-installed in the housing. The fiber positioning and cable retention clamps are crimped to the cable components, as described in a following section. The stripped and cleaved fiber ends are inserted in the alignment guides, and the fiber and cable clamps inserted in their respective recesses in the splice housing. Since the splicing machine precisely positions the scribing tool with respect to the fiber clamps, each stripped fiber end is cleaved at a point which places the end slightly past the center of the alignment guide. Thus, when both fibers are fed into the guide a slight bow is incurred in the fibers which provides a light mutual spring force to maintain the fiber ends in contact.

After assembling the two pairs of fiber ends in the two alignment guides and the clamps in their recesses, the splice housing cover is snapped shut, using spring catches to hold the two parts together. The splice is complete.

The first model of the splice housing is being machined from aluminum bar stock. After experiments to verify the design, 10 housings will be made for the interim repairs to be delivered to CECOM. The interim repair samples will be sealed with a compressible sheet gasket between the cover and housing base.



CECOM TEMPORARY SPLICE HOUSING

FIGURE 2

2.3 Splicing Machine Design

2.3.1 Design Considerations

The design of the tool kit for preparing the fiber optic cable and cleaving the fibers is of central importance to the functioning of the field splice system. The basic concept is to mount all of the tools on one frame to make up a splicing machine entity. This manually operated machine must be portable as part of a kit, and simple to manipulate by non-technical personnel under adverse field conditions. Precision of clamp placement, of the fiber scribing and of housing and parts positioning must be maintained by fixtures, rather than by operator skill.

Considerable thought and effort have been devoted to designing the equipment to meet the above requirements. An important operation is the scribing and cleaving of the fibers to precise length and with smooth ends, perpendicular to the fiber axis. Our experience with the Optalign (R) connector and commercial splice has resulted in a reliable approach to scribing and cleaving fibers for the field splice system. First a nick is made in the fiber at a predetermined point. The scribed fiber is then cleaved. The cleave originates at the scribed nick, propagating through the fiber. Cleave angles of less than 2 degrees are typical and are more than adequate for low loss wet connection.

To test the fiber cleaving approach for this application, a working model of the scriber was constructed. This model will be used as part of the first complete brassboard model of the entire Field Expedient Splice Kit which will be constructed during the next six months.

2.3.2 Description of the Splicing Machine

A splicing machine has been designed and detailed. The main frame and many of the parts will be made of aluminum alloy for the structural integrity and low weight. Prior to constructing a working prototype of the splicing machine, a full sized wooden model was fabricated. This model affords us the chance to test the placement of working parts and tools for ease of operation. A series of photographs was made of the wooden version and is shown in Figures 3 to 18 to aid in describing the design and operation of the splicing machine.

Following is a summary of the splicing procedure for two fiber, double jacketed cable, of the tight buffer type.

1) Stripping of Cable Jackets

The cable is placed in a clamp on the right hand side of the machine frame (Figure 3). The six inch length of cable protruding through the clamp opening is controlled by a stop(not shown)on the base plate. The lever in the upper right hand corner of the machine is pulled toward the operator to close the clamp jaws, which have properly sized blades to cut through the cable's outer jacket. The cable is then pulled out of the jaws, to the right without retracting the blades. The severed jacket is thus caused to slide off, leaving the Kevlar strength member strands exposed. The Kevlar is folded back along the cable and the inner jacket is stripped in a similar manner, by simply positioning the partially stripped cable in the adjacent, smaller bladed, jaws and repeating the above operations.

2) Attachment of Strength Member Retainer

The strength member retainer is made of two parts: the strain/retain ring; and the crimping sleeve, shown on the cable in Figures 4 and 5 and also pictured in Figure 19. The strain/retain ring is slipped

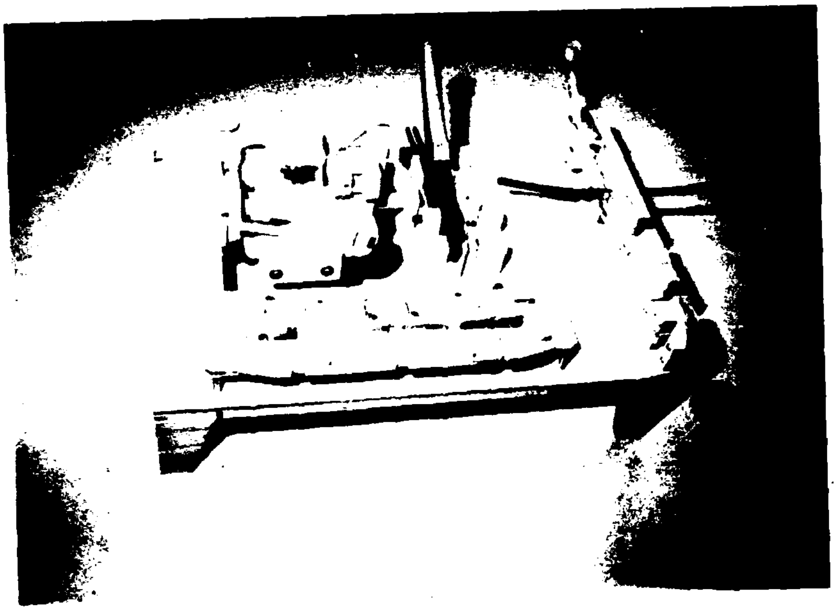


FIGURE 3. Cable in Place for Stripping of Jacket

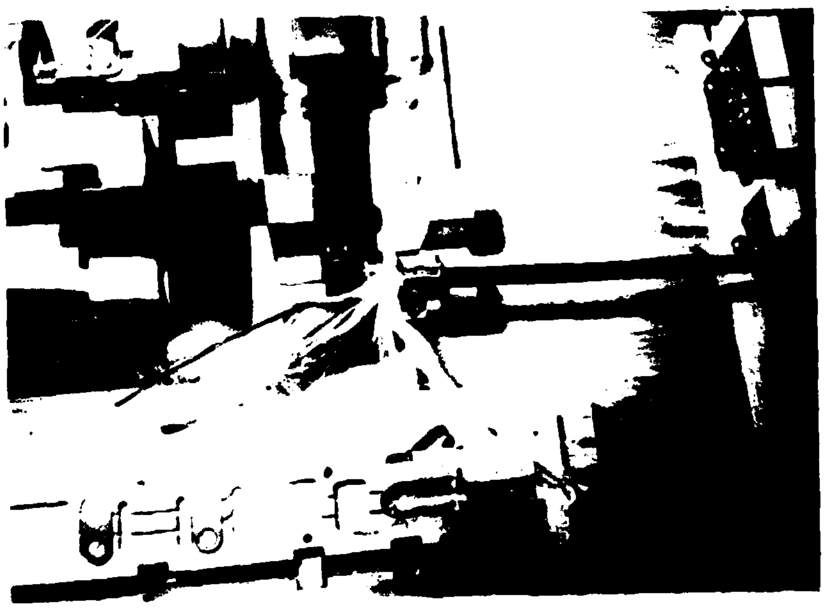


FIGURE 4. Strain/Retain Ring on Cable

over the cable and placed at the end of the outer jacket (Figure 4). The Kevlar strands are folded back over the ring and the crimping sleeve is placed over the Kevlar, trapping the strength member strands between the convoluted surface of the ring and the sleeve. The excess Kevlar strands are snipped off, the retainer is positioned in the jaws of a crimping tool (Figure 5), and the sleeve is crimped. The crimping tool is not actually shown in the photograph, but is similar to the fiber locater sleeve crimper in the adjacent holder.

3) Attachment of Fiber Locater Sleeve

The individual fiber locater sleeve, with a rubber inner sleeve, is slipped over one Hytrel jacketed fiber and placed in the jaws of the crimper as shown in Figure 6. The fixture serves as a positioner to retain the sleeve for precise location of the cleaved fiber end produced in a later step. The crimping tool is manually closed to crimp the sleeve over the fiber jacket. Figure 7 shows the sleeve after crimping. The inner rubber sleeve protrudes to one side, serving as a spring to force the metal sleeve against one side of the fixture and, later, against the distal side of the splice housing cavity, for repeatable positioning.

After crimping the locater sleeve on one fiber, the same operation is performed on the other fiber.

4) Stripping of Fiber Jackets

The Hytrel fiber jackets are mechanically stripped using a stripper mounted on a slide, shown in retracted position in Figure 8. The tool is moved to the right as the jacketed fiber end is inserted in a ferrule at the end of the stripping tool. The handle is depressed and the stripper slide is then moved to the left, as shown in Figure 9. This action strips the fiber to the required length (Figure 10). The operation is repeated for the second fiber.

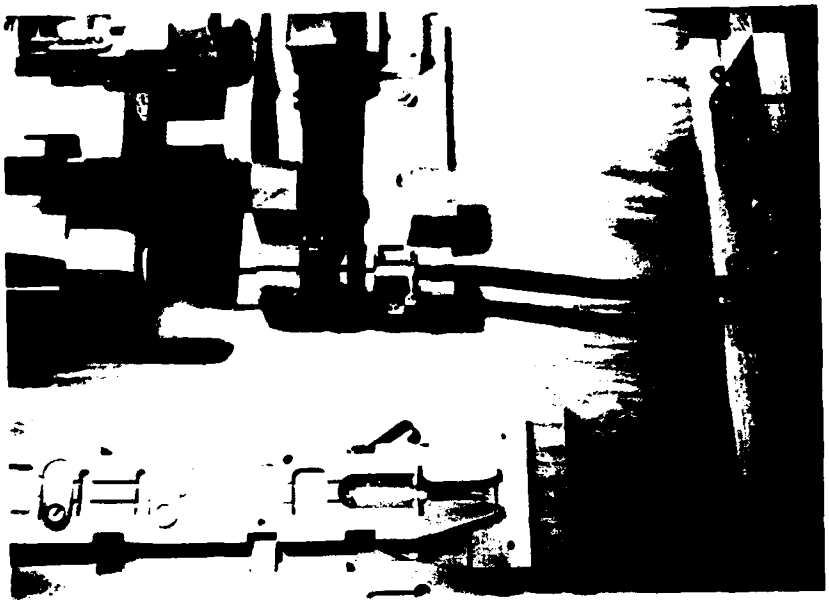


FIGURE 5. Crimping Sleeve in Place

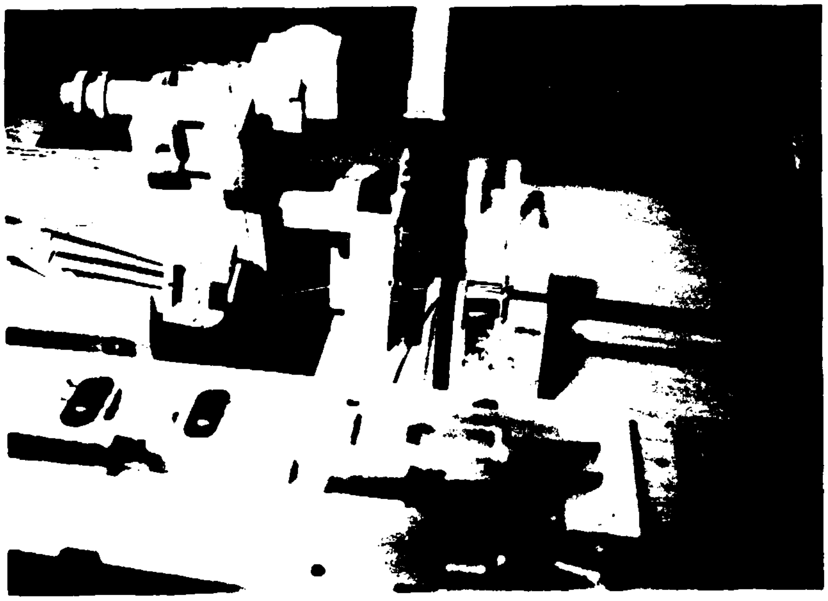


FIGURE 6. Fiber Locator Sleeve Crimping

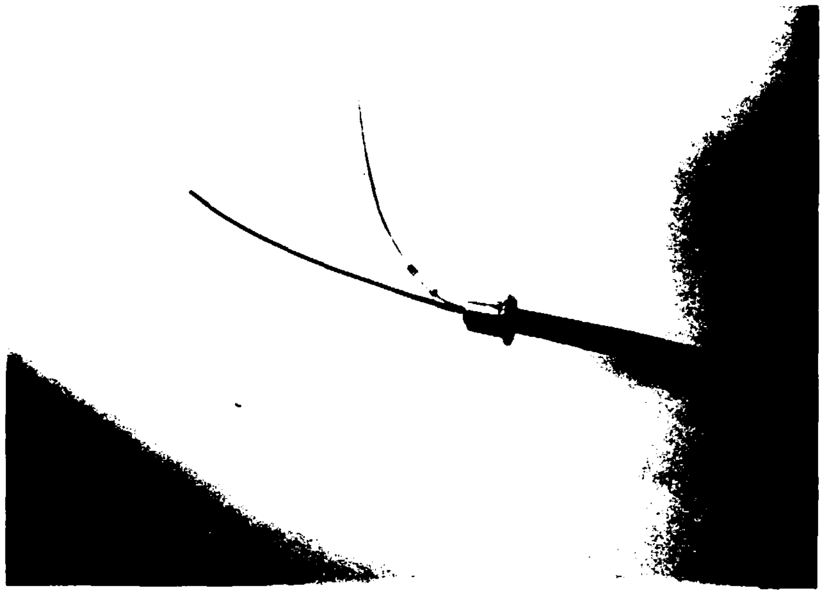


FIGURE 7. Crimped Locator Sleeve

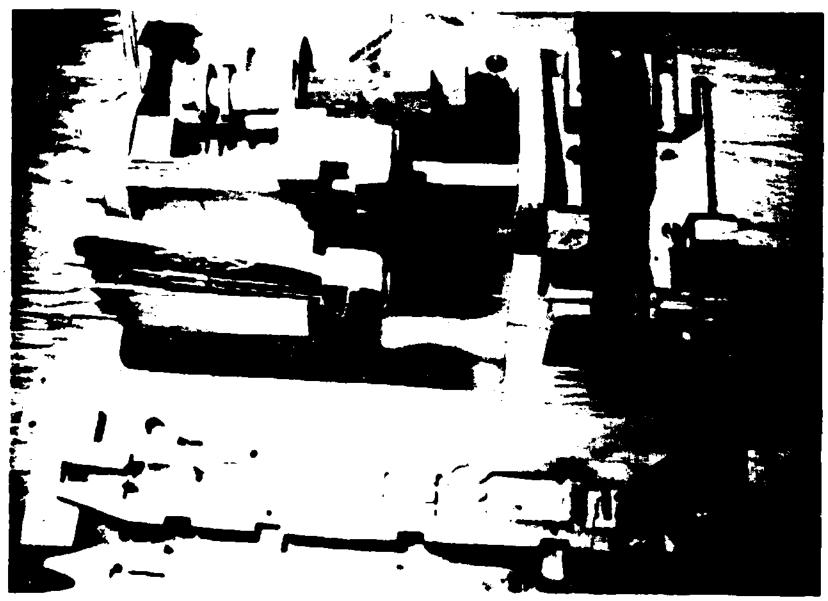


FIGURE 8. Fiber Before Stripping Fiber Jacket

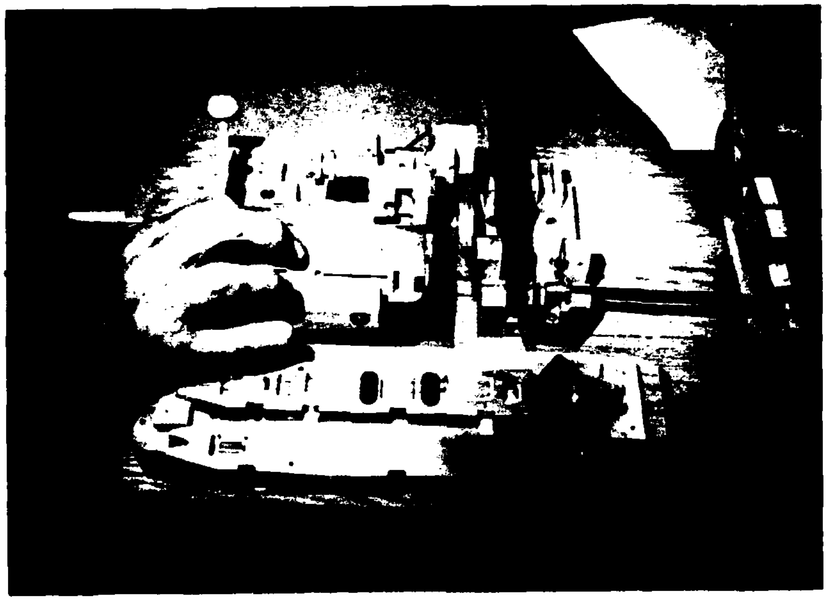


FIGURE 9. Stripping Fiber Jacket

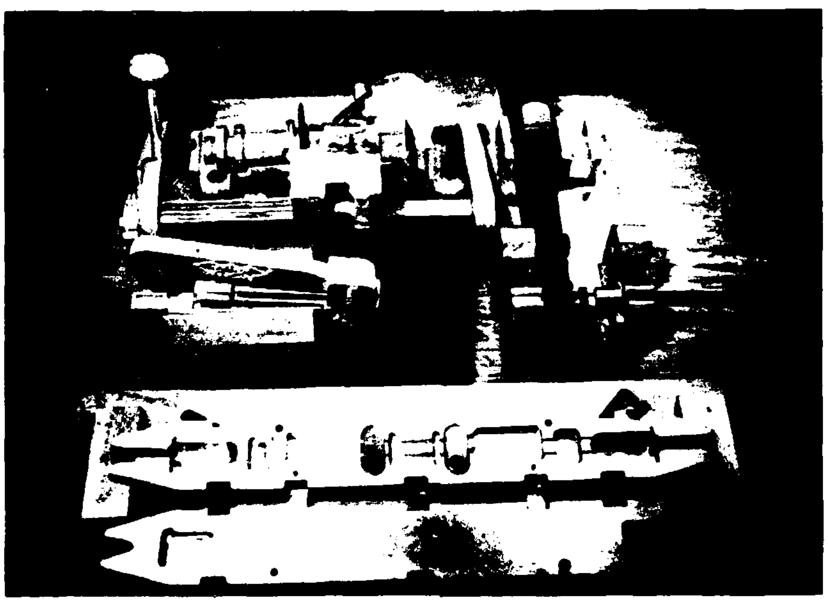


FIGURE 10. Fiber After Stripping

5) Scribing and Cleaving the Fibers

The fiber stripper, used in Step (4), and the scribing/cleaving tool, are mounted on a common cradle, manipulated into either of two positions by the lever in the upper left hand portion of Figure 10. Pulling the lever toward the operator rotates the scribing/cleaving tool 90^{o} into position to work on the fibers. Figure 11 shows the cradle in position for scribing. The fiber jacket is then clamped in place and the fiber is scribed and cleaved. The fiber has been cleaved in Figure 13. The second fiber is cleaved in the same manner.

6) Completing the Splice

a) The prepared cable end is removed from the holding clamp, and placed in the clamp closest to the operator. The strength member retainer is placed in the cavity in the splice housing, as shown in Figure 14, and the right hand clamp lever is pulled forward to hold the cable. The fibers are fed into the individual alignment guides through enclosed feed slots which insure entry into the guide via the flares. When the fiber locater sleeves are inserted in their proper housing cavities, the cleaved fiber ends will be correctly positioned in the alignment guides, a few thousandths of an inch beyond the guides' centers. The hinged cover of the splice housing is then closed and the spring clips turned and snapped into place (Figure 15). The cable clamp is released and the splice housing is picked up, rotated end for end, and replaced in the fixture (Figure 16).

b) Steps (1) through (5) are repeated with the other end of severed cable. The splice housing is reopened and the prepared cable is assembled in the guides and cavities, as described in (6a). This time,

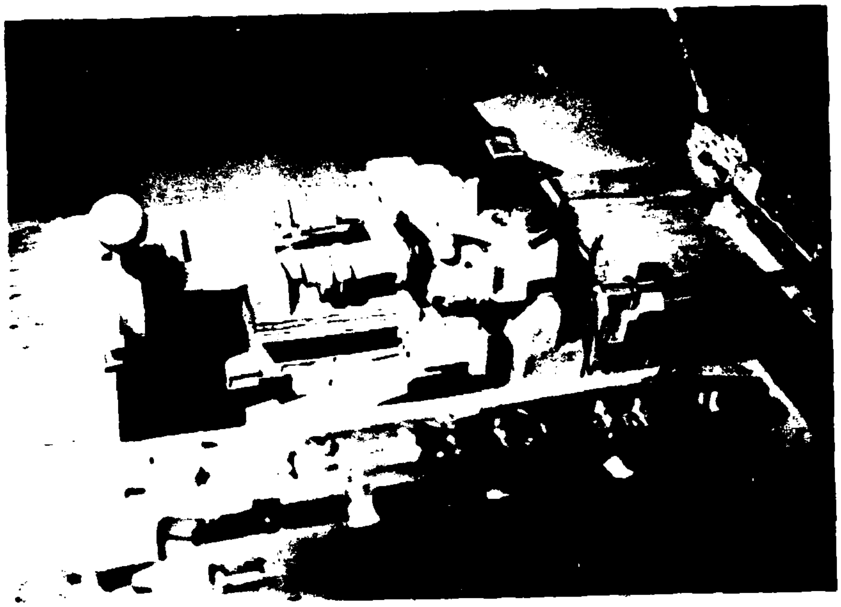


FIGURE 11. Cradle in Scribing Position

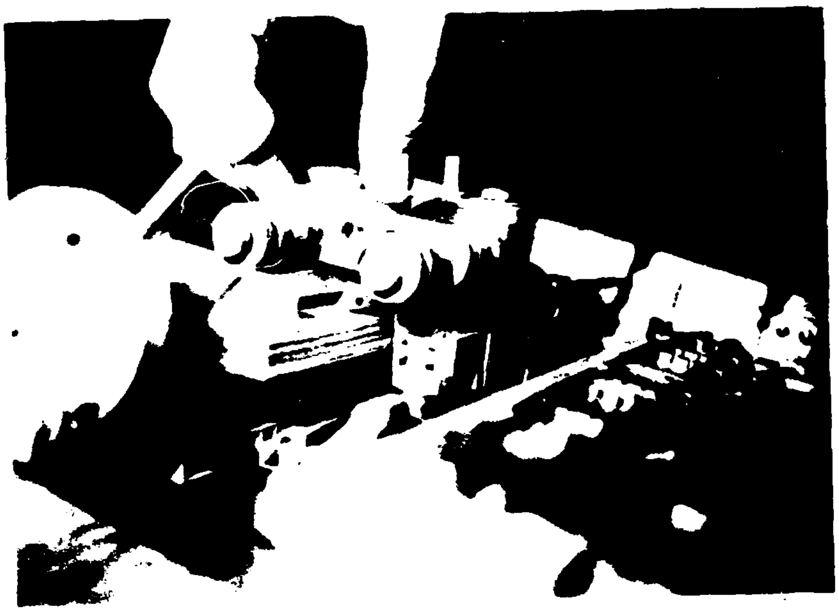


FIGURE 12. Scribing Fiber

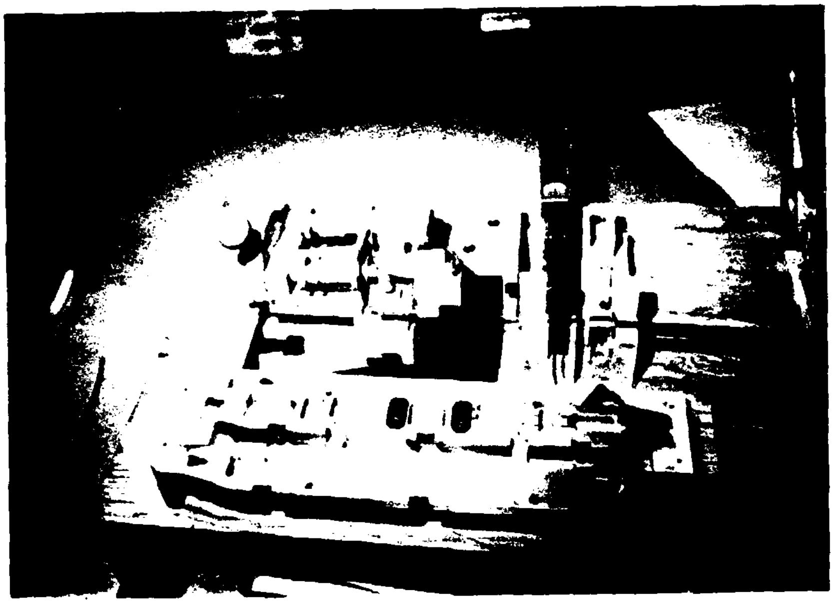


FIGURE 13. Fiber Cleaved to Length

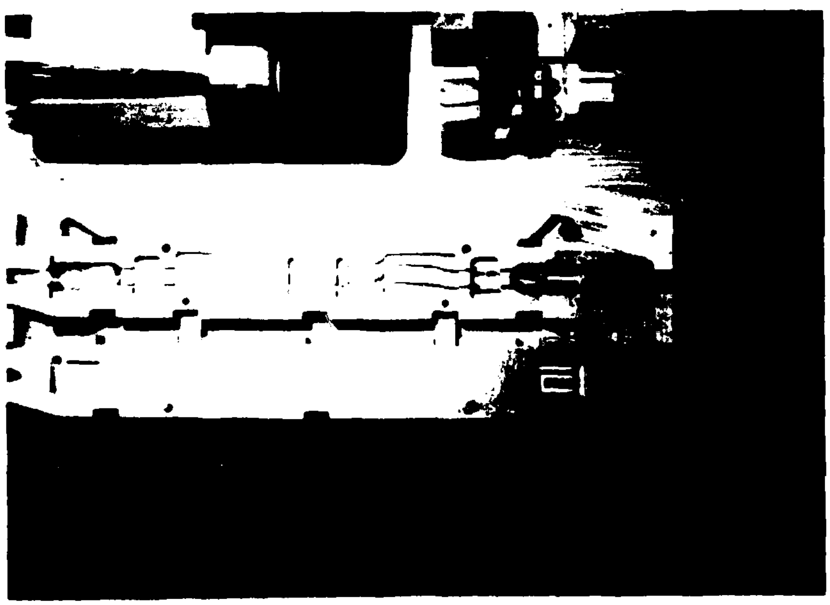


FIGURE 14. Cable Installed in Splice Housing

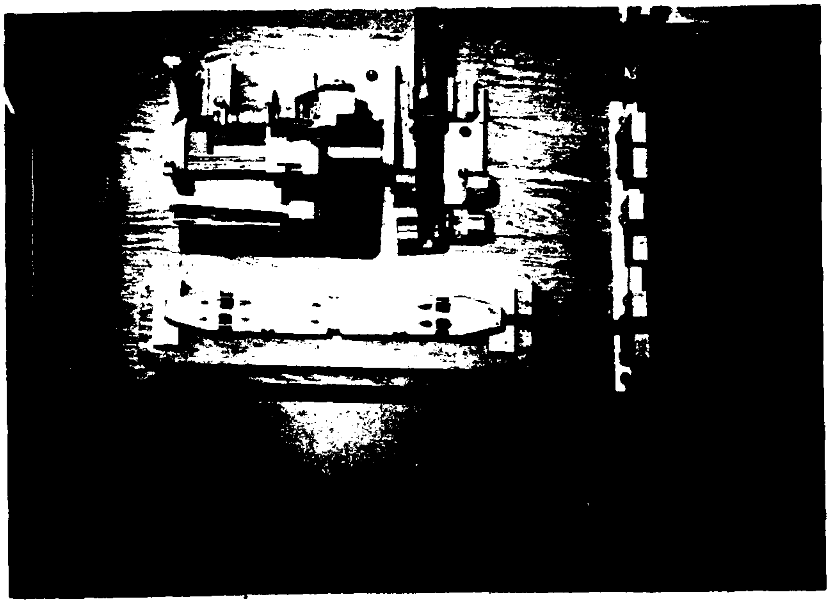


FIGURE 15. Splice Housing Closed

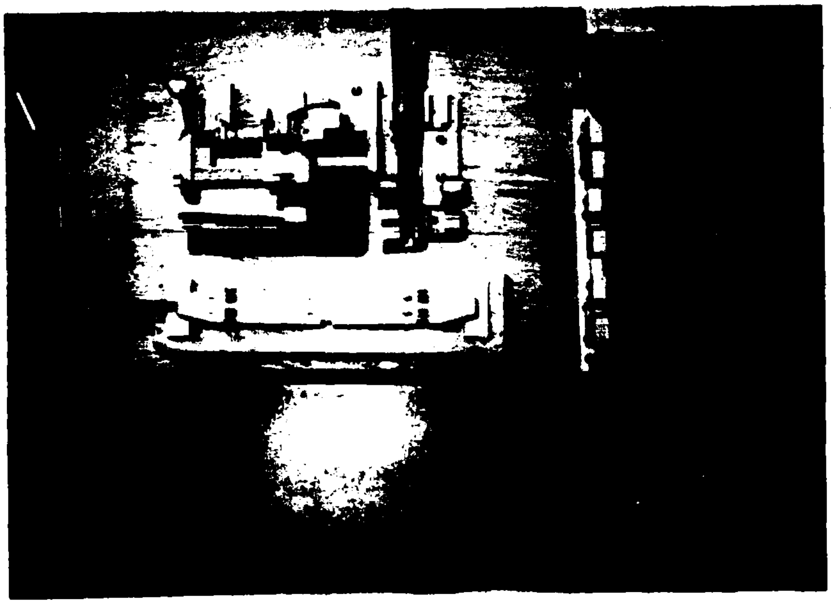


FIGURE 16. Splice Housing in Second Position

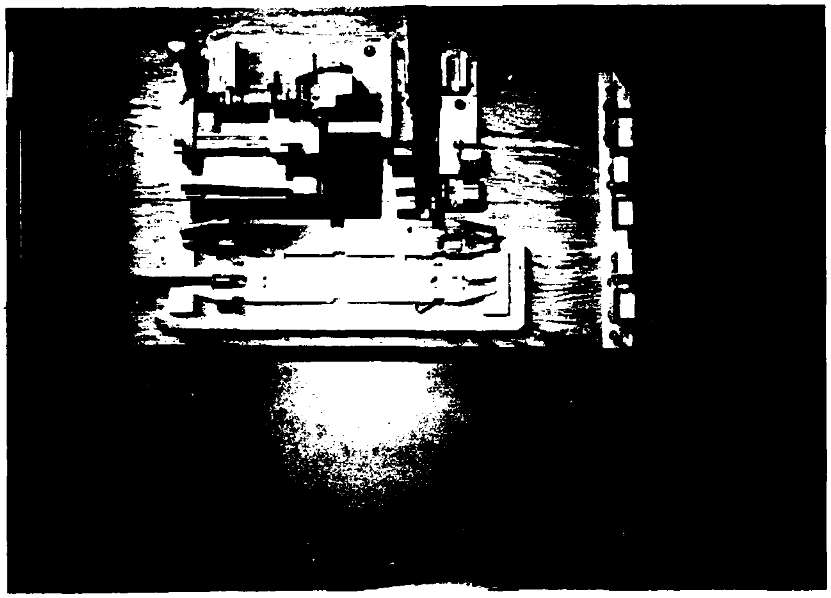


FIGURE 17. Splice Housing Opened Before Assembly of Second Cable End

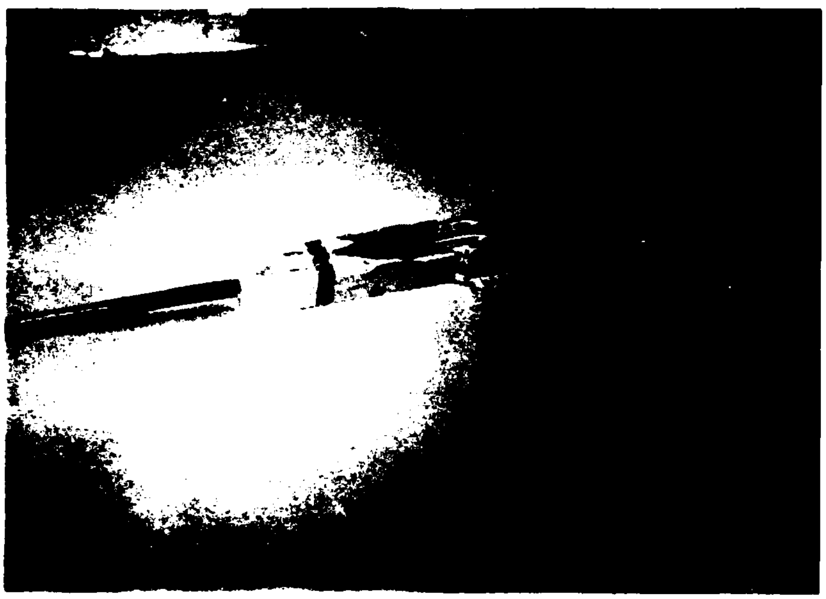


FIGURE 18. Completed Splice

when the fibers are installed in the guides, the cleaved ends contact the previously inserted fibers to effect optical channel restoration.

c) The housing is again closed, clips engaged and cable clamp released. The finished splice is shown in Figure 18, after removal from the splice machine.

2.4 Splice Performance

The splices, as described above, have not yet been made and tested. Tests of commercial connectors and splices using the alignment guide have been performed, however. In tests of 25 splices of 125/50μm fiber with UV cured epoxy in the alignment guides, the insertion loss was 0.1 to 0.2 dB. The silicone oil to be used in the guides for the field splice kit performs equally well, as demonstrated in tests of demountable connectors using that medium.

Later in the program, completed splices will be subjected to tests of insertion loss, as well as to a series of environmental tests enumerated in the Test Plan.

2.5 Project Status and Future Work

The design work is nearly complete prior to construction of the first working splicing machine model. The detailed drawings are being completed and revised according to the information gained through the construction of the wooden models. The scriber/cleaver has been ordered and should be completed in June, 1982. Modifications of crimping tools are in progress. The remaining parts and assemblies of the splicing machine will be ordered in June.

The first working model of the splice enclosure, and internal parts, has been constructed. Preliminary evaluations and design improvements are in progress. Cost estimates are being obtained for die casting (aluminum alloy) and molding (reinforced plastic) of the splice housing.

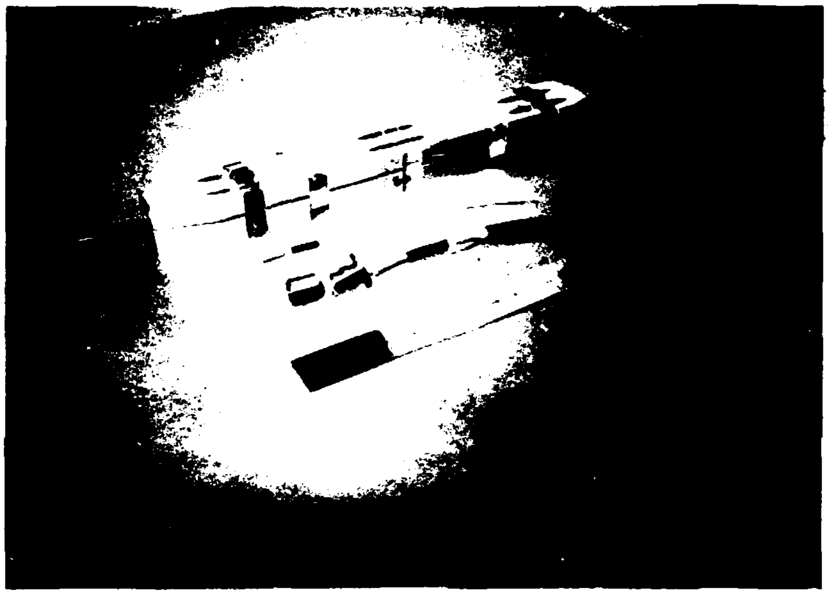


FIGURE 19. Completed Splice and Crimping Parts

It is not economically practical to make the housings by machining, beyond the first few models. The number of parts to be machined prior to die casting or molding will be resolved with CECOM.

By September, 1982, it will be possible to demonstrate the operation of the splicing machine model to make completed splices.

3.0 CONCLUSIONS

The development of a viable field splicing system for fiber optic cables is proceeding close to the schedule. The construction of wooden models and working subassemblies has enabled us to solve many problems during the design phase. There are no unresolvable problems apparent at the present stage of development .

REFERENCES

1. Hodge, Malcolm H., "A Low Loss Single Fiber Connector Alignment Guide", FOC 1978, Proceedings, pp 111-115

2. Hodge, M.; Larkin, J.; Ryley, J.; Woods, J.,"Splices and Connectors for Single and Multimode Optical Fibers", SPIE, January 1982, Los Angeles, California.

APPENDIX A

CORADCOM — CENCOMS 22-81

Technical Requirements — 5 May 1980

Field Expedient Repair of Fiber Optic Cables

1. Scope: These are the technical requirements of an exploratory development program to establish a technique for the emergency repair of fiber optic cables at the Army's Organizational level (i.e., in the field environment). The repair method must be applicable to cables containing one to six optical fibers and be easily accomplished in a variety of weather and temperature conditions typical of tactical field environments. The engineering effort shall include development of the repair method; testing of the repaired cable; development and fabrication of any special tools for effecting the repair; the assembly; packaging and delivery of a repair kit containing materials and tools needed to effect the repair; and recommendation on cable improvements to facilitate cable repair.

2. Applicable documents: The following documents form a part of these requirements:

Specifications: Military - DOD-D-1000B - Dated 28 Oct 77, Drawings, Engineering and Associated Lists.

Standards: MIL-STD-810C dated 10 March 1975, Environmental Test Methods

DOD-STD-1678 dated 30 Nov 1977, Fiber Optics Test Methods and Instrumentation.

3. Requirements:

3.1 General Requirements: The objective of this program is a method of repairing fiber optic cables in the field environment. The repair method shall be designed as an expedient repair method to minimize "down time" of the fiber optic link and to reduce the cost of maintenance of the cable by eliminating the need to replace long (1 Km) connectorized sections of the cable for every repair. The repair method shall be suitable for integration into the Army's fiber optic cable maintenance program.

It is expected that the repair method will be the adaption of a single fiber splice or connector technique to cables containing one to six optical fibers. Of primary importance is the achievement of low (optical) loss in a repair method that is easy to implement. In addition, the program shall aim at achieving ruggedness and good strain relief of the repair, ease of break-out of fibers from the cable, and repair (e.g. by means of the addition of a section) when no slack exists in the cable (taut cable). Special tools, equipment or protective housings needed to accomplish the repair shall be devised and fabricated as necessary. Techniques and tools shall be designed to eliminate or minimize human contact with glass splinters from the optical fibers.

The effort shall be conducted in three phases: design, testing and demonstration.

In the initial (design) phase of development, simplicity, low loss, and ruggedness shall be verified in the laboratory.

In the test phase of the program, the contractor shall devise and perform simple tests for mechanical strength and optical integrity of the repaired cable. In addition, the repaired cables shall be subjected to accelerated aging in controlled environmental chambers to test for any deterioration which may result from exposure to various environmental conditions.

In the demonstration phase, the contractor shall prove that the repair method is suitable for field use by conducting sample repairs outdoors under various weather conditions at the contractor's site.

For any conditions under which the repair method may not appear useful (e.g. Arctic temperatures of -55°C), the contractor shall conduct an investigation culminating in recommendations of additional hardware or equipment that will allow performance of the repair, or of alternate maintenance procedures for those conditions.

3.2 Applicability of the Repair Method: The repair method shall be applicable to the following types of cables and optical fibers:

3.2.1 Cables: The repair method shall be applicable to commercially available cables containing one to six optical fibers. The investigation shall include, but not be limited to the two fiber and six fiber cables produced by Galite (semi-loose tube), ITT (tight buffer) and Siecor (loose and filled buffer). Figure 1 show cross-sections for typical single and multi-fiber cables. Fibers within the multi-fiber cables are helically wound around a central strength member.

When less than six optical fibers are required for transmission, the cable may contain strength members or fillers in place of unneeded optical fibers.

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3.2.2 Optical Fibers: Typical properties of the optical fibers contained in the cables are follows:

Type	glass core/glass clad; graded index
Numerical Aperture (N.A.)	.14 - .24
Glass Fiber Diameter	125 μm
Irregularity in Diameter	±5%
Tensile Strength	50,000-100,000 psi (typical)

3.3 Specific Requirements of the Repair Method:

3.3.1 Loss: The loss introduced into a fiber path by the repair method shall be measured for all repairs prior to environmental testing. The loss shall not be greater than nominally 1 dB. Contractor shall adapt the attenuation measurement specified in test method 6020 of DOD-STD-1678, Procedure III, to the present application. Details of the test method and equipment shall be provided to the PCO for approval. Measurements may be made at a nominal wavelength of .82 μm. The loss measurement shall be performed in the laboratory.

3.3.2 Simplicity: The repair method shall be easily accomplished with simple-to-use tools/equipment in a variety of environmental and weather conditions.

3.3.3 Implementation Time: The time required for effecting the repair shall be minimized. It shall not exceed fifteen (15) minutes.

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3.3.4 Break-Out of Fibers: In multi-fiber cables, jacketing material extruded over the fibers may coat the fibers on all sides making the breaking-out (freeing) of the fibers from the cable a delicate, time consuming operation. The repair method shall incorporate a means to rapidly break-out the fibers. A tool shall be designed and fabricated if necessary. Recommendations on improving cable structure to enhance repair methods shall be made.

3.3.5 Strain-Relief: The repair method shall include a means for strain relief of the repaired cable. Reference: TM 11-5995-208-15, Operator's, Organizational, Direct Support, General Support, and Depot Maintenance Manual Including Repair Parts and Special Tools Lists, CABLE ASSEMBLY, SPECIAL PURPOSE, ELECTRICAL CX-11230/G (NSN 5995-00-133-9126) AND CABLE ASSEMBLY, ADAPTER CX-10734/G (NSN 5995-00-133-9125).

3.3.6 Taut Cable: The repair method shall be usable on a taut cable. It may be necessary to insert a length of cable, thus requiring application of the repair method twice, once on each end of the inserted piece of cable.

3.3.7 Strength of Repaired Cable: The repair method shall include a means of maintaining or restoring strength to the repaired section of the cable. The strength of undamaged cable and of the repaired cable shall be measured by adapting the method entitled "Cable Tensile Load," Method 3010 of DOD-STD-1678, Procedure I, to the repaired cable. Test method shall be submitted to the PCO for approval.

3.3.8 Protection from Environment: The repair method shall include a means of protecting the repaired section from deterioration as a result of exposure to the environment.

3.4 Environmental Tests: Repaired cables shall be tested in a variety of environments. Detailed test methods including the cable lengths and optical test measurements and equipment shall be provided to the PCO for approval prior to the start of the tests. Tests shall be conducted in the laboratory using environmental chambers to control the conditions to which the cables are exposed.

Loss/attenuation (paragraph 3.3.1 above) shall be monitored during each environmental test in order to determine whether any deterioration of optical transmission is induced by the environment.

At the completion of each test, the repaired cable shall be inspected visually under 5X magnification and any physical deterioration shall be noted. Also, at the completion of each environmental test, the repaired cable shall be subjected to the strength test (Section 3.3.7 above).

A minimum of five repaired cables, including one, two and six fiber cables, shall be subjected to each of the environmental tests listed in paragraphs 3.4.1 to 3.4.9 below. The objective in each case is no increase in loss from the value measured in 3.3.1, and preservation of mechanical integrity and strength.

3.4.1 <u>High Temperature</u>: Method 501.1 of MIL-STD-810. Procedure II. The temperature for Step 7 shall be 85°C (135°F). The loss shall be measured in Steps 7 and 10. Step 8 shall be omitted.

3.4.2 <u>Low Temperature</u>: Method 502.1 of MIL-STD-810. Loss shall be measured after the 24-hour stabilization period of Step 2 and in Step 7. Steps 3, 4 and 5 shall be omitted.

3.4.3 <u>Temperature Shock</u>: Method 503.1 of MIL-STD-810. The loss shall be measured in Step 7.

3.4.4 <u>Solar Radiation (Sunshine)</u>: Method 505.1 of MIL-STD-810. Procedure II.

3.4.5 <u>Rain</u>: Method 506.1 of MIL-STD-810. Procedure II. Total time of exposure to rain shall be two hours (Step 4).

3.4.6 Humidity: Method 507.1 of MIL-STD-810. Procedure III.

3.4.7 Fungus: Method 508.1 of MIL-STD-810. This test need not be carried out if all parts and materials used in the repair of the cable have already been shown to have passed this test.

3.4.8 Dust (Fine Sand): Method 510.1 of MIL-STD-810.

3.4.9 Leakage (Immersion): Method 512.1. Procedure I and Procedure III. Water shall be used in both procedures.

3.5 Tests for Field Use: Simple tests for use in the field shall be devised and used to determine optical integrity and mechanical strength of the repaired cable.

3.5.1 Optical: The test may consist of detecting a signal of known intensity that has been transmitted through the section of cable containing the repaired portion.

3.5.2 Strength: Simple procedures for tugging, twisting and bending the repaired cable shall be devised for maintenance personnel to determine that the repaired cable is mechanically strong.

3.6 Demonstration of Field Use: Contractor shall demonstrate suitability of repair method for field use by performing at least one single and one multifiber cable repair in each of a variety of weather conditions at the site of contractor's plant.

3.7 Additional Hardware/Equipment; Alternate Maintenance Methods: In the event that the repair method, while generally useful, fails to be suitable for implementation under certain conditions, contractor shall conduct an investigation resulting in specific recommendations as to additional hardware

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or equipment that may extend the usefulness of the method, or an alternate method of cable maintenance for those conditions.

3.8 Models: Ten (10) sample repairs representative of the work accomplished, shall be submitted at the end of the 13th month of the program. Ten final repairs and six (6) complete repair kits shall be delivered by the end of the 25th month. The procedure for accomplishing and field testing the repair shall be specified in step-by-step instructions included with the kit.

The repair kits shall contain materials and tools or equipment for effecting repairs in the field. Kits shall be lightweight, rugged, and in a form that is easy for one person to carry and use.

3.9 Engineering drawings and description of any tools or equipment designed or modified from existing designs under this program shall be delivered by the end of the 25th month.

4 Quality Assurance Provisions:

4.1 Acceptance shall be based on the contractor's fulfillment of the requirements of Section 3.

5 Packaging:

5.1 Packaging, packing, and marking shall be as specified in the contract.

6.1 Notes: This section is not applicable to this specification.

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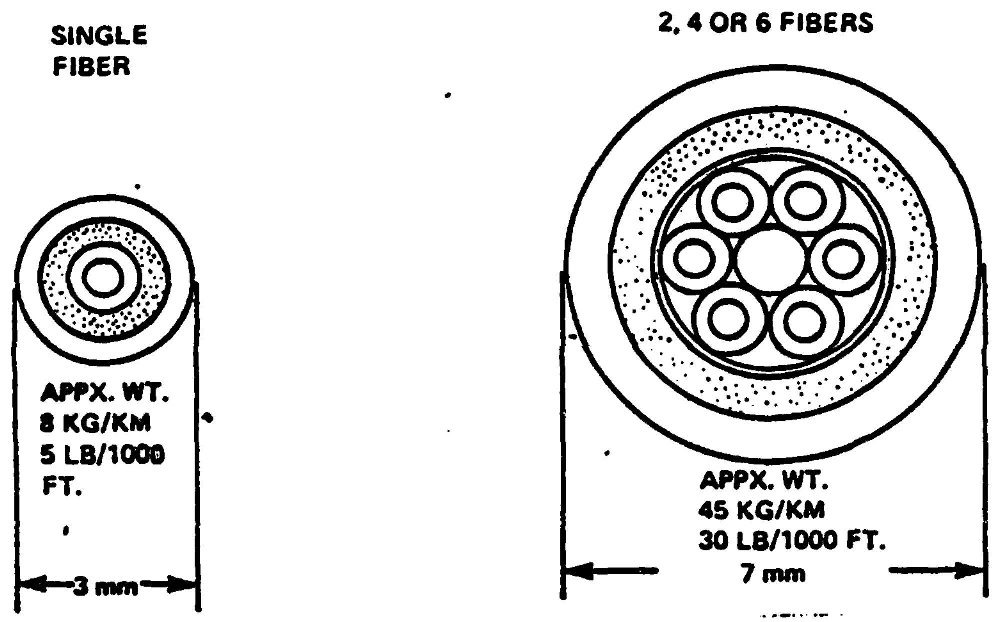

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